2. MAINTENANCE OF PROJECT FEATURES

2.1 Introduction

All flood control works (FCWs) must be properly maintained to provide the protection for which they were designed. Remember that as the public sponsor, you are solely responsible for ensuring that the FCW is properly maintained and will protect the lives and property of your families, friends, and taxpayers. Even if you have sub-agreements with local landowners who routinely perform project maintenance, these landowners are not ultimately responsible for the operations and maintenance of the FCW. If landowners fail to perform needed maintenance or correct deficiencies on their property, it's your duty to ensure that the maintenance and repairs are completed. Proper maintenance of the FCW must be taken very seriously, and local plans and budgets need to be structured so that the maintenance of each project feature is carried out on a regular and continual basis. In addition to providing for usual operations and maintenance expenses, this budget needs to account for the replacement of more expensive project components such as pumps, motors, gates, and corrugated metal pipes as they age and come to the end of their design life.

This chapter identifies many of the activities that are necessary to maintain flood control works. The following sections provide maintenance recommendations, requirements, and examples of the types of deficiencies that will reduce the project's eligibility status within the Rehabilitation and Inspection Program (RIP), which is described in chapter 6. To avoid confusion between the baseline requirements that the U.S. Army Corps of Engineers has established for inclusion in the RIP and the additional suggestions and recommendations that are provided in this chapter, please refer to the Corps' Inspection Guide, found in Appendix C. The Inspection Guide is used in Corps inspections of all non-Federally constructed FCWs, and lists the specific requirements for inclusion in the RIP. This listing is not all-inclusive and some Corps districts may specify additional requirements based on local conditions. More information on Corps inspections is provided in chapter 7.

Note that many of the pictures in this chapter are labeled with the words "*ACCEPTABLE*", "*MINIMALLY ACCEPTABLE*" and "*UNACCEPTABLE*." The ratings are provided here along with the pictures in order to give you a better understanding of the standards that the Corps uses while inspecting flood control works across the country. The ratings given are the ones that a Corps inspector might assign to the project feature if it was observed during a routine inspection. A definition of these ratings is provided in chapter 7.

2.2 Erosion (Applicable to all FCWs)

a. Types of Erosion

There are several types of erosion that effect FCWs. For example, the slopes of any embankment can become eroded from rain runoff, as shown in Figure 2.1 or by embankment overtopping, as in Figure 2.2. Depending on the extent of the erosion, the level of protection provided by the FCW can be significantly reduced. In cases of embankment overtopping during a flood, there may be a total failure of the structure.

Figure 2.1 *UNACCEPTABLE erosion of levee slope. (TX)*

A second type of erosion often seen on embankments is wave wash. Under high water conditions, wave action can form long terraces along the length of the embankment slopes. If additional material or bank protection is not provided, the embankment will continue to cave as the waves work their way farther into the slope. Further discussion on the treatment of wave wash is provided in Appendix D of this manual.

Figure 2.2 *Flood damage. (WA)*

A third type of embankment erosion is caused by the flow of water within a river or channel. These flows can erode a channel bank or levee, or undermine other flood control structures and cause them to cave into the water. Bank caving or stream bank erosion can be a very serious threat to the stability of an FCW. It's critical that the riverward bank be inspected for bank caving or erosion. If the river or stream bank erosion or caving is observed to be moving in the direction of a levee or floodwall, immediate action should be taken to stabilize the banks.

Figure 2.3 *Slope failure on bank protection project. (WA)*

b. Repair of Areas Damaged by Erosion

All erosion gullies like those pictured in 2.1 need to be repaired to prevent further erosion and more significant damage during high water. The ground should be scarified and backfilled with the same type of material that the levee is made of. The backfill material should generally be placed in 6 inch layers and compacted mechanically or by hand, in order to restore the original shape of the levee. Additionally, since this erosion is typically a reoccurring problem, something should be done to improve the drainage and prevent further erosion in the area. Consideration should be given to installing drainage channels or appropriately sized rock, and areas of the levee that remain exposed should be reseeded and mulched. Please refer to section 2.7, below, for details on the placement of riprap. In extreme cases of channel/ bank erosion, a relocation or setback of the levee may be the only economical solution.

2.3 Encroachments (Applicable to all FCWs)

Excavations, structures, or other obstructions present within the project easement area are generally prohibited. Fencing that prohibits access along the crown of the levee is prohibited. Where access control is needed, the public sponsor should install gates that will allow continued access along the crown of the levee for surveillance and flood fight activities. The Corps may make certain exceptions to this rule, provided the encroachment does not impact the operation, maintenance, or structural integrity of the project. Figures 2.5 through 2.14 are examples of common encroachments that should not be permitted.

Figure 2.4 *ACCEPTABLE. Landowner has not encroached on levee easement area and has stayed back 10 - 15 feet. (MN)*

Figure 2.5 *MINIMALLY ACCEPTABLE. Field encroaches on levee easement. The landowner has tilled the soil right to toe of the levee, and was requested to stay back at least 10 feet. (ND)*

Figure 2.6 *UNACCEPTABLE levee encroachments. This landowner tilled near one third of the way up the landward levee slope. (MN)*

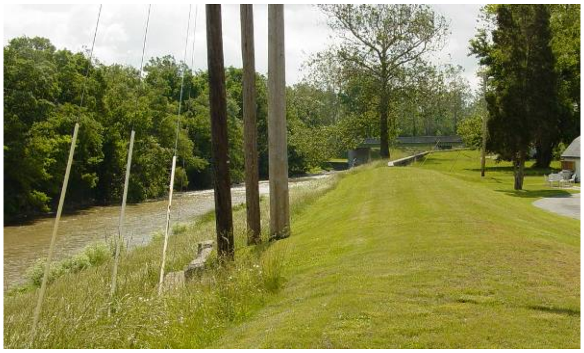

Figure 2.7 *UNACCEPTABLE levee encroachments. Utility poles in levee embankment. (IN)*

Figure 2.8 *UNACCEPTABLE encroachment. Piping for lawn irrigation system drilled through levee without approval. (ND)*

Figure 2.9 *UNACCEPTABLE encroachments on earthen levee. Fallen woody debris requires removal. (KS)*

Figure 2.10 *UNACCEPTABLE, unapproved encroachment. Material stockpiled against the levee. (OK)*

Figure 2.11 *UNACCEPTABLE encroachment. Residential and rural fences crossing the levee. (ND)*

Figure 2.12 *UNACCEPTABLE, unapproved encroachment on levee easement (fencing). (OK)*

Figure 2.13 *UNACCEPTABLE encroachment. Gardens and compost bins located on levee crest and riverward slope. (ND)*

Figure 2.14 *UNACCEPTABLE encroachment. Patio construction using railway timbers and fill without approval. (ND)*

2.4 Slope Stability (Applicable to all FCWs)

Some earthen materials tend to become saturated with water very easily. When this happens, they loose stability and can't support their own weight. If a stream or river embankment is composed of these materials, the embankment will slump off and move down the slope into the river, causing a bulge at the base of the slope. When river banks break down like this, they are said to have slope stability problems and need to be repaired. Slope failures can lead to serious problems, especially if the failure occurs near a levee or floodwall. Figures 2.15 through 2.17 show examples of slope stability problems.

Figure 2.15 *UNACCEPTABLE. Slope failure and erosion caused by inadequate channel bottom and side slope protection. This was a direct result of bottom scouring that undercut the levee slope and erosion caused by turbulent flow at the end of the bank protection. (ND)*

Figure 2.16 *UNACCEPTABLE. Slope failure and erosion on a channel improvement project. (MN)*

Levees, like riverbanks, are subject to the same soil saturation effects during a flood or period of heavy rainfall. Levees are generally less susceptible to slope stability problems because of the materials they are made of and because of their shallow slopes. However, slope failures have occurred during prolonged periods of high water or heavy rainfall. Figure 2.16 shows an earthen embankment that failed as floodwaters receded. While slope failures will generally occur on the riverward slope of a levee, be aware that slope failures on landward slopes are also possible. A levee should be carefully inspected for slope stability problems after these events.

Figure 2.17 *UNACCEPTABLE earthen embankment failure. (MN)*

Figure 2.18 *Classic picture of a tree causing slope failure. (WA)*

A related slope failure/ stability problem involves trees growing on or near the channel or levee slopes. It's very important to prevent tree growth near levee or channel embankments, because when the roots of these trees decay they leave voids in the soil, which allow water to quickly saturate the slope and cause a slope failure. Trees can also be uprooted and deflect flood flows into the embankment, accelerating the erosion of the bank.

The classic signs of slope stability problems are listed below, and you should watch for these signs during routine inspections. Please also refer to section 2.9 for further discussion on levee cracking.

a. Wide deep cracks that parallel the riverbank or levee crest. In the case of levees, these cracks may also extend down the slope of the levee.
b. Vertical movement of the material along the crack. Remember that this movement may be very obvious like in Figures 2.16 or 2.17, or very subtle if the stability problem is just starting to develop.
c. If the slope has slumped or is starting to slump, examine the area along the toe of the embankment. In many cases there will be a noticeable bulge in the slope or riverbank.

Deep seated sliding often requires the removal and replacement of that section of the levee or river slope, and the stabilization of the area with a soil or rock berm. If you identify signs of a developing slope stability problem, it is very important that you contact your local Corps district office for an investigation and to get technical assistance as to the best way to repair the problem.

2.5 Removal of Debris (Applicable to all FCWs)

Any accumulations of drift, grass clippings, and other objectionable materials deposited on the riverward side of any FCW or along the crown and side slopes of a levee must be removed and disposed of at suitable locations outside of the floodway. When debris collects in a flowing channel, it can deflect the water towards the channel bank, causing significant damage to the FCW. Figure 2.19 shows the result of what started out as a beaver dam that was not removed, which expanded into a log jam. Before this log jam was removed, both the inside river bank and the levee experienced severe bank erosion. Log jams have endangered bridges and railway crossings, and they lead to higher flood crest elevations upstream of the obstruction.

Figure 2.19 *UNACCEPTABLE erosion of river channel, caused by a log jam. (ND)*

One common problem experienced along urban levees is that the residents pile lawn clippings and yard waste on the riverward side of the levee. This practice should not be allowed because the clippings will kill the grass cover that protects the levee. During a flood, the debris gets washed away, exposing the levee material to erosion.

2.6 Animal Control (Applicable to all FCWs)

Close attention must be given to the presence of burrowing animals, since they may not be readily detected without a thorough inspection. Burrows created by gophers, muskrats, opossums, badgers, and other animals can lead to rapid levee failures during floods. For this reason, an active animal abatement program needs to be implemented to remove these animals. Rodent control techniques involving fumigation, bait stations, bait broadcasting, or trapping have proven effective in certain situations, but you should always contact your state's Fish and Game Agency, Department of Natural Resources, or Wildlife Agency to determine which rodent control procedures are allowable and recommended in your area.

Figure 2.20 *Animal burrow in a levee. (IA)*

Inspections to detect the presence of burrowing animal activity are generally most effective immediately after the levee has been mowed. Animal burrows that are identified should be thoroughly excavated and inspected, backfilled with compacted soil that is similar to material of the levee, and reseeded. This will avoid the possibility of water piping through unfilled portions of the burrows during a flood.

Beavers pose an additional concern in streams and channel improvement projects. They have been known to cause problems by building dams, blocking culverts, and by burrowing into the stream bank to create a den. When beaver activity is noted, the beaver should be removed and the dam and blockages removed. Failure to correct the problem may result in increased bank erosion and slope stability problems in the area of the beaver den during periods of high water.

Figure 2.21 *Beaver dam. Such dams can stop flow within the channel and cause erosion to the channel banks. Sponsors are encouraged to remove beaver dams ASAP. (ND)*

Figure 2.22 *Beavers attempting to block the culvert passing through a gated embankment. (MN)*

2.7 Riprap Revetments and Banks (Applicable to all FCWs)

As shown in Figure 2.23, riprap can be a very effective method for protecting a riverbank or flood control feature from erosion. However, if the riprap protection is not placed correctly, it can cause eddy currents to erode unprotected areas of the bank upstream or downstream of the project, as shown in figure 2.24.

Figure 2.23 *Flood damage on a naturally protected bank, as compared to damage on an adjacent bank which was protected with riprap. (Note that even though the riprap clearly protected the area during the flood, if it was observed an inspection it would have probably been rated Minimally Acceptable because the grass would have prevented an inspector from properly examining the riprap.) (WA)*

Figure 2.24 *Channel erosion located at the upstream end of a flood control levee protected by riprap. Erosion caused by riprap protection and eddy currents. (MN)*

For riprap protection to be effective, it's important to ensure that it is properly maintained. During project inspections, look for settled areas that may indicate the riprap is being undermined by the river, ice, or debris. When undermining or rock displacement occurs, additional rock will need to be added to restore the even slope. When the rock protection is uneven the flow turbulence will increase, resulting in additional erosion of the project or of areas upstream or downstream of the project.

The protected area needs to be kept free of unwanted brush, saplings, and trees. Unwanted vegetation should be sprayed with an appropriate herbicide to kill the plant, and the root system should be removed. Failure to control the sapling and tree growth can result in the trees being uprooted during a flood, displacing the riprap and increasing the rate of erosion.

Figure 2.25 *ACCEPTABLE riprap for erosion control. (MT)*

Figure 2.26 *ACCEPTABLE riprap for erosion control. (NE)*

Figure 2.27 *MINIMALLY ACCEPTABLE. Trees and saplings are becoming established within riprap-protected areas and along the lower portions of the river channel, and must be removed. (ND)*

Figure 2.28 *UNACCEPTABLE. Tree and sapling growth is well established within the riprap protection on an earthen levee. This overgrowth must be removed. (MO)*

Any areas of stone riprap that have settled, moved, or been damaged by erosion should be filled in with hard, durable rock of suitable size or with a six-inch filter-blanket layer or a layer of geotextile fabric under the stone riprap, between the soil and the rock. These sublayers allow the water to pass from the soil, yet prevent the fine soil from washing out from under the stone riprap. It's very important that you contact the Corps for technical assistance when installing geotextile fabrics, as the Corps has significant experience in installing riprap over geotextile fabric, and can help you to avoid complications with the process.

When selecting stone for riprap, choose durable rock that's insoluble in water. Stratified or easily crumbled rocks such as shale, or rocks such as claystones that are likely to decompose in water are not good for riprap. Stone for riprap should be block shaped with a specific gravity of at least 2.5. Smooth rounded stone or flat, thin, elongated and slab stones are not recommended. As a general rule, no more than 25% of the stones distributed throughout the gradation should have a length more than 2.5 times longer than the other dimensions, and none of the stones should be 3 times longer than their width or thickness.

Grouted riprap should be avoided unless it is absolutely necessary. The surface of grouted riprap can look perfectly fine until the bond between the grout and the rock fails. Grouted riprap can fail suddenly if it is undermined, and this can lead to unexpected and catastrophic failure of the slope. Other objections to using grout include the cost of installation, the lasting environmental impact, and the undesirable aesthetics of having a cement-lined stream bank as opposed to a plain rock bank.

It should be noted that work within a river channel which involves placing or adding material (soil or rock) may require a Section 404 permit from the Corps. Please contact your Corps district before placing any material along the banks of a river or stream to determine whether you will need a permit for the work. If the FCW is damaged by a flood or by high-water and is eligible for rehabilitation assistance under PL 84-99 as discussed in later chapters of this manual, the Corps will help you to obtain the necessary permits.

The Corps can provide recommendations or materials on the proper sizing, gradation, thickness, use of geotextile fabrics, and other details related to the placement of riprap.

2.8 Vegetation (Levee Specific)

The Corps' policy for landscaping around levees, floodwalls, and embankment dams, is found in EM 1110-2-301. The requirements are sometimes seen as being excessive and out of touch with contemporary environmental concerns, but as the primary function of a levee is to protect communities from flooding, the Corps' maintenance requirements have been established to reduce the chance of catastrophic failures during high water. If you'd like a variance to the Corps' vegetation requirements (allowing additional vegetation on or around the levee) then you need to contact your local Corps district. A variance would be granted if the proposed vegetation is seen to preserve, protect, or enhance natural resources, or if it protects the rights of Native Americans. Such variances will only be granted if the vegetation retains the safety, structural integrity, and functionality of the levee; retains the accessibility for inspection and flood fighting purposes; and doesn't reduce the level of protection required by the National Flood Insurance Program or the RIP if the levee is a part of these programs. Specific items relating to the maintenance of levee vegetation include the maintenance of the grass or sod cover and the removal of unwanted bushes and trees.

a. Maintaining and Promoting a Good Grass or Sod Cover

Grass or sod cover is one of the most effective and economical means of protecting flood control levees and drainage swales against erosion caused by rain runoff, channel flows, and wave wash. As the public sponsor, you are required to ensure the grass cover has every opportunity to grow. This will require that you periodically fertilize, water, and mow the grasses as needed. In addition, every effort must be made to prevent unauthorized encroachments, grazing, vehicle traffic, the misuse of chemicals, or burning during inappropriate seasons. Failure to properly maintain the grass cover can result in unnecessary erosion and possible embankment failure.

Figure 2.29 *MINIMALLY ACCEPTABLE. This photo shows cattle grazing on the levee. Cattle typically don't harm the sod cover to the extent that sheep or other animals do. In this case, the landowner and the public sponsor were informed of the Corps' policy that grazing is not permitted on levees or within the levee easement area.*

b. Mowing

Periodic mowing is essential to maintaining a good ground cover. Levees should be mowed regularly in order to control weeds and to prevent the growth of brush and saplings. Long grasses and native prairie grasses are one of the many challenges facing the project inspector. Long grasses (greater then 12 inches in length) can make a visual inspection nearly impossible and can hide serious concerns such as rodent activity, levee slides, and cracking; all of which can lead to the failure of the levee. For these reasons, the grass should be mowed to a minimum height of 3 inches. The last mowing of the season should be accomplished under conditions that will allow the grass to grow to approximately 8 to 10 inches by the winter season. It's important to ensure that the entire levee profile has been mowed, including zones extending 15 feet beyond the toes of the embankment, which should be free of all woody growth and should be clear of other obstructions so that a truck could drive beside the levee if needed.

Figure 2.30 *UNACCEPTABLE levee with knee-high grass, making visual inspection nearly impossible. (MN)*

c. Control of Trees, Brush, and Weeds

If the public sponsor mows the levee at regular intervals, the growth of saplings, trees, and brush will not become a problem. However, if the levee is not mowed regularly, the resulting growth will make it difficult to properly maintain and inspect the project. Trees and brush can also affect the stability of the structure and interfere with emergency operations during high-water conditions. All trees and brush must be cleared and disposed of away from the flood control project. The disposal of material on the riverward side of the levee or areas where flood waters can carry the material downstream is prohibited. In riprap protected areas, ditches, or in other areas of the project where power mowing is impractical, the unwanted vegetation should be controlled with an approved herbicide spray or should be cut by hand. Herbicides must be used in accordance with state

Figure 2.31 *UNACCEPTABLE. Levee is mowed but trees and longer grasses within levee easement area. Trees are greater than 2" in diameter. (MN)*

Figure 2.32 *UNACCEPTABLE long grasses and trees on levee side slopes. (ND)*

and local laws and regulations. Any trees that reach 2 inches in diameter or greater, and are located on the levee, riprapped areas, drainage channels, or within 15 feet of the toe of the levee must be cut down, the root ball removed, the voids filled with impervious material, and the fill material firmly compacted and reseeded.

2.9 Cracking (Levee Specific)

It's important to closely monitor and evaluate all visible areas of cracking on a levee or riverbank, to ensure they don't develop slope stability problems as shown in Figure 2.35 and discussed in section 2.4. Cracks in a levee develop when the levee material is saturated with water and when it is overly dry. Clay, like most impervious materials, will shrink as it dries and re-expand when wet. Clay levee surfaces tend to shrink and expand slightly, and some cracks in the surface of the FCW are to be expected. Shrinkage cracks are generally narrow and shallow, not extending more than more then a few inches into the levee, but during long periods of drought they may extend as much as two feet into the levee. These cracks can run longitudinally or transverse to the levee, as in Figure 2.33, or may appear as blocks as shown in Figure 2.34. If the cracking becomes excessive, it needs to be corrected even if the levee appears to be stable. It's important that you contact your local Corps district office for guidance on how to repair cracks observed in your levee.

Figure 2.33 *ACCEPTABLE cracking in clay levee with shrinkage cracking caused by dry conditions. (MN)*

Figure 2.35 *UNACCEPTABLE embankment cracking and slope failure. This photo shows what started out as cracking along the crest of the embankment and quickly developed into a slope failure. All cracking located on a levee or riverbank must be closely monitored. (MN)*

Figure 2.34 *UNACCEPTABLE cracking with landside pooling, Whitehead Levee Project, (IA)*

2.10 Ruts and Depressions (Levee Specific)

Ruts and other depressions often develop along levees or patrol roads as a result of pedestrian or vehicular traffic, settlement, or because of an inadequate crown slope. Sometimes the levee material over a culvert can settle, leaving a trench across the crown of a levee. This process and related maintenance is discussed below in section 2.20. Ruts and depressions are a problem because they allow water to pond on the levee crest or access road. If left uncorrected, the ponded water will seep into the levee's interior or into roadway embankment, saturating the foundation material, and making the levee more susceptible to failure during a flood. The levee or access road should be inspected for ruts, pot holes, and areas of standing water after it rains.

To correct these problems, the topsoil and sod should be removed and the existing levee surface should be roughened. This is ideally done when the ground is not frozen; if there are ice crystals in the ground then the entire frozen layer should be removed. Loose fill material should be added evenly, in approximately 6 inch layers. Add water or dry the backfill materials as necessary to attain optimal moisture content during compaction. Compact in place by hand or mechanical methods in order to bring the levee back to its original shape. The topsoil should be replaced and the area should be reseeded and mulched for erosion control.

Figures 2.36 through 2.39 show common ruts which can hold water on access roads and levees.

Figure 2.36 *MINIMALLY ACCEPTABLE levee rutting caused by pedestrian and bicycle traffic. (ND)*

Figure 2.37 *UNACCEPTABLE ruts in levee crown require fill. (MO)*

Figure 2.38 *MINIMALLY ACCEPTABLE ponded water along a levee crest. (MN)*

Figure 2.39 *UNACCEPTABLE rutting in levee. (OK)*

When the crest of the levee is used for recreation, inspections, surveillance during floods, and flood fighting activities, a surface treatment (e.g., gravel, crushed rock, pavement, etc.) should be provided to reduce the deficiencies listed above. This is not a requirement but it is recommended for active levees.

2.11 Underseepage Control Berms (Levee Specific)

Underseepage control berms, also known as seepage berms, perform two functions in controlling seepage. First, they provide a downward weight to counteract the upward force of the seepage pressure within the foundation material adjacent to the levee, which is where the pressure is highest. Second, seepage berms lengthen the seepage path, which increases the flow resistance and decreases the seepage pressure in the area beyond the berm. The berms should be constructed with material at least as permeable as the existing levee to reduce the chance of increasing dangerous build up of hydrostatic pressures within the levee. They should be thoroughly inspected both before and after each flood along with the rest of the FCW, and any cracks, depressions, settlement, or other problems identified need to be repaired as outlined in previous sections of this chapter.

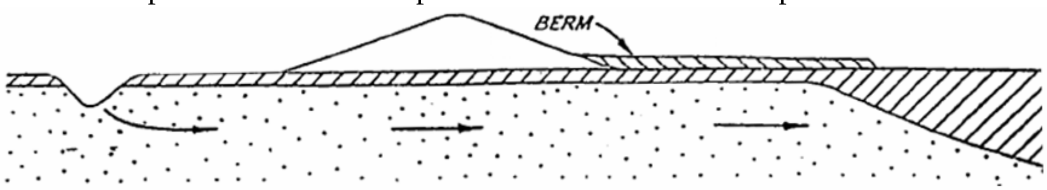

Figure 2.40 *Sketch of a seepage berm.*

2.12 Excavations (Levee Specific)

The removal of levee blanket materials may endanger the levee by increasing the potential for seepage or stability problems. Any excavation that is proposed within the boundaries of the levee easement or right-of-way should be reviewed by the Corps. This review may result in a recommendation to not allow the excavation, or to recommend restrictions on the excavation in order to maintain the project's eligibility for rehabilitation assistance. The areas the public sponsor should monitor for excavation activities include the levee itself, and those areas within 100 feet, both landward and riverward, of the levee.

2.13 Utilities (Levee Specific)

It's also recommended that you coordinate the construction of any utilities that cross over, under, or through levees or other flood control structures with the Corps prior to the start of construction. During the installation of the utility, care needs to be taken to ensure that pipes do not leak, and that there is adequate compaction around the utility. Failure to provide good compaction will allow for seepage along the pipe during a flood. Once installed, the utility trench will need to be monitored for cracks, depressions, settlement, sink holes, or saturated soils that may indicate a leak or possible seepage along the utility line. These types of problems should be brought to the utility company's attention as soon as they are discovered and repaired expeditiously. Additional guidance on the placement of utilities on or through a levee can be provided by your local district office.

2.14 Underseepage Relief Wells/ Toe Drainage (Levees and Floodwalls)

Relief wells are used to relieve hydrostatic pressures in the foundation of a levee, which is caused by fluctuation in the water table or seepage under a levee or flood control structure during a flood. Typical relief wells consist of a well screen, a filter pack (granular material surrounding the well screen), a riser, and an outlet system. Relief wells, over time, can become less efficient at relieving hydrostatic pressures because of clogging of the filter pack, sedimentation build up in the well screen, and/or bio-fouling. Clogging of the filter pack and sedimentation within the relief well occurs when the foundation material migrates into the filter pack, making it less permeable and reducing the well's effectiveness. Bio-fouling is the build up of bacteria on the well screen itself, reducing the area in the screen through which water can flow.

Maintenance of relief wells requires surging and pump testing of the well, and comparing the results to the test results recorded when the well was initially installed. Well testing and clearing should be accomplished by qualified well drillers. You can request technical assistance from the Corps on the proper procedures and/or a list of qualified well drilling contractors in your area.

2.15 Seepage/ Sandboils (Levees and Floodwalls)

Sandboils and seepage problems are not generally identified during routine inspections because these problems typically only appear under high water conditions. However, if sandboils or continuously saturated soils (not caused by ponded water or poor drainage) are observed on the landward side of the levee or floodwall under low water conditions, regardless of their size, they will likely become serious problems under high water conditions. Sandboils and underseepage is a serious problem that should not be taken lightly. If sandboils are observed during a flood or low water conditions, or if there's evidence that foundation material is being (or has been) removed from the levee foundation, then the Corps should be contacted to evaluate the situation and provide technical advice regarding repairs. Appendix D of this manual provides additional information regarding seepage and sandboils.

Figure 2.41 *Evidence of sandboils. (IN)*

2.16 Closure Structures (Levees and Floodwalls)

Closure structures must be in good repair. Placing equipment, stoplogs, sandbags, and other materials must be readily available at all times; stored nearby on the protected side of the levee, or stored on a trailer for quick transportation to the site. It's important that all components are clearly marked and that installation instructions and related procedures are readily available. You should regularly check your inventory of all components of the closure structure to ensure that stoplogs and other components will be there when you need them. Note that when aluminum stoplogs are stored, they should be supported along their entire length so they don't deform during extended periods of storage.

Figure 2.42 *ACCEPTABLE floodgate in a levee. (KS)*

2.17 Concrete Surfaces (Applicable to all concrete structures)

Visible cracking, scaling, or spalling are signs of concrete movement and stresses within the concrete. Cracks in concrete walls that aren't repaired are subject to freeze / thaw damage, which widens the gap and leads to additional spalling of the concrete. When examining any concrete flood control structures, spalling, scaling, or cracking should be very minimal. Figures 2.43 through 2.47 show various degrees of cracking, spalling, and scaling.

Figure 2.43 *MINIMALLY ACCEPTABLE 1/8th inch crack extends through concrete floodwall and needs to be sealed to prevent further damage. (MN)*

Figure 2.44 *MINIMALLY ACCEPTABLE Vertical floodwall crack with spalling. The rating for this particular crack is Minimally Acceptable because the crack is still tight but there is some spalling occurring as well. (MN)*

Figure 2.45 *UNACCEPTABLE exposed rebar. Monolith joint separation with exterior spalling along the joint and interior spalling in the area of the rebar. (MN)*

Figure 2.46 *Detail of the crack in Figure 2.45, showing the exposed rebar that tied the two monoliths together. (MN)*

Figure 2.47 *MINIMALLY ACCEPTABLE floodwall. Exposed surface rebar resulting from poor construction practices. The public sponsor has painted over the rebar in an attempt to keep it from rusting. (MN)*

Fire and extreme heat can also be very damaging to concrete, and sponsors should discourage fires from being built beside concrete structures. Common grass or incidental fires are not typically a great concern, but repeated hot or large fires such as bon fires, camp fires, or brush fires can cause spalling in the concrete. Even though fire damage is not specifically listed in the Corps' FCW Inspection Guide (Appendix C), the related spalling, cracking, or other damage would be noted during an inspection and is something that should be taken seriously. If this type of damage is identified, efforts must be made immediately to stop fires near the FCW. Depending on the extent of the damage, the integrity of the structure should be investigated and repairs should be made as soon as possible.

Over time, concrete surfaces will weather, leaving the concrete rough to the touch, or will hold moisture on the surface. When this occurs consider applying a protective coating to the concrete to help prevent moisture from entering the structure. By applying a protective coating to the concrete surface and sealing the cracks the chances of freeze / thaw damage will be greatly reduced, increasing the life expectancy of the structure. Prior to the application of a concrete sealer the structure should be cleaned, existing cracks should be sealed with a flexible sealant, and any spalling repaired. Any sealer chosen for the concrete floodwall should be a water or solvent-based acrylic protective coating, which may be either clear or colored, and may be textured. A clear system should contain at least 23% solids by weight, and a colored system should contain at least 67% solids by weight and 46% solids by volume.

More serious damage such as spalling should be repaired as soon as it is identified, especially if steel reinforcing has been exposed. Perform concrete repairs with a polymer-modified Portland cement mortar that will provide a minimum or 2500-psi compressive strength in two hours. For repairs greater than 1 1/2 inches deep, add 3/8-inch clean-washed pea gravel so that aggregates don't result in variations of the physical properties of the mortar. Limestone gravel is not acceptable. All surfaces to be patched need to be structurally sound, clean, and free of loose debris, oils, vegetation, paints, sealants, and other contaminants. Remove all deteriorated concrete to a minimum of ¼-inch in depth. Cut edges should be square with the concrete surfaces, and not feathered. Surfaces should be sufficiently rough to ensure a good bond. Any existing reinforcing bars should be thoroughly cleaned. If required, existing concrete should be removed to fully expose the reinforcing bar. Sandblasting may be required to clean them thoroughly. All surfaces should be fully saturated and freestanding excess water should be removed before applying the repair material. The material should be placed in the prepared area starting from one side and working to the other side. For vertical areas, trowel the material in an upward motion over the repaired area. Successive applications must be troweled against the previously placed material just prior to hardening. Work the material firmly into the bottom and sides of the repair. Level the material to the desired thickness and close up edges of the repair with a trowel. Finish the material to match the existing concrete finish. Remove any material applied or spilled beyond the desired areas. All exposed surfaces should be thoroughly saturated with water immediately after finishing.

2.18 Tilting, Sliding, and Settlement (Applicable to all Concrete Structures)

If soil conditions were poor prior to construction or if there has been inadequate soil compaction, concrete structures (floodwalls, pump stations, and gate wells) will frequently show signs of settlement. As the structure settles it may begin tilting in the lateral or transverse directions, settle vertically, or may even begin to slide downhill, if constructed on a slope. As the pressure within the concrete builds cracking and large spalls will develop. If the movement is considerable like that shown in Figures 2.48 and 2.49, a licensed engineer should be contacted to determine the best approach to correct the problem, or to closely monitor the structure during high water to avoid a structural failure.

Figure 2.48 *MINIMALLY ACCEPTABLE floodwall. Monolith joint separation caused by settlement, no landward or riverward tilting. The opening is about 3 inches wide at the top but the rubber joint sealer is still intact and undamaged. This joint has since been repaired by bolting another joint sealer on the both sides of the wall and filling the void with an expandable joint sealer. (ND)*

Figure 2.49 *UNACCEPTABLE monolith movement in floodwall. The monolith shown in the photo has tilted about 6 inches riverward as well a vertically. Note the movement when compared to the adjoining monolith and the top cap. As the monolith moved considerable spalling has occurred along the joint. This project is monitored very closely during flood events. (ND)*

Figure 2.50 *ACCEPTABLE. Decorative floodwall is in straight alignment, with no tilting or spalling, and all joints are tight together. (MN)*

2.19 Vegetation (Floodwall specific)

Vegetation must be removed from both sides of floodwalls for maintenance, flood fighting activities, and to protect the floodwall from damage from roots. Roots under a floodwall can greatly accelerate seepage rates during high water, increasing the chance of sandboils on the landward side and potentially leading to the failure of the structure. For these reasons, you should maintain a zone extending 2.5 meters (8') beyond both the underground toe and heel of the floodwall, keeping it free of everything but grass or sod, or possibly riprap on the riverward side. Since the floodwall may have been constructed in the shape of an inverted T, the underground toe and heel may extend several feet past the visible base. Additional guidance on landscaping around levees, floodwalls and embankment dams can be found in EM 1110-2-301, as referenced in Chapter 1.

Figure 2.51 *UNACCEPTABLE. Trees growing too close to floodwall. (KY)*

Figure 2.52 *UNACCEPTABLE. Trees growing too close to floodwall. (KY)*

2.20 Internal Drainage Systems

Figure 2.53 *UNACCEPTABLE interior drainage at the toe of an earthen levee. (OK)*

During non-flood conditions, rainwater is permitted to drain naturally through culverts in the levee and into the river. However, during high water, the gates on the drainage culverts are closed, and rainfall and flood seepage becomes trapped within the protected area of the FCW. If there is insufficient ponding area within the FCW, the water will need to be pumped over the levee or floodwall and into the river. Even if a levee operates exactly as intended to keep the river back, a community can still be flooded from within if the interior drainage system is not functioning properly.

Some of the features of an interior drainage system include ponding areas, drainage swales or ditches, inlet and outlet structures including gates and concrete components, culverts, gate wells, and pump stations. Natural or modified streams or ditches within the protected area are generally not considered part of the flood control project unless specifically stated in the project design. However, don’t forget that you could still experience significant damage from seepage and rain runoff if these channels are not maintained.

As the public sponsor, it's your responsibility to ensure that all ditches, drainage structures, and other components of the project are kept in an acceptable condition. All drainage structures should be inspected and maintained at least once a year prior to flood season and again after periods of high water. The following paragraphs describe the maintenance of some components of interior drainage in greater detail.

a. Drainage Ditches

Drainage ditches should be maintained to ensure that the capacity of the ditch is not decreased by heavy vegetation growth or sedimentation. As part of a good maintenance program, the drainage ditches should be cleared at scheduled intervals and restored to the original channel design grade and cross section. Material removed from drainage ditches should be removed from the floodway, and not left in area near the banks. Removal of the excavation spoils will improve water quality and help to prevent further flooding and maintenance problems. During an inspection, drainage ditches are rated on flow capacity, sedimentation, vegetative growth, and cross section. Regularly scheduled maintenance will ensure the flood control project performs in a satisfactory manner during high water.

Figure 2.54 *ACCEPTABLE interior drainage channel. (IA)*

Figure 2.55 *MINIMALLY ACCEPTABLE vegetation (cat tails and bull rushes) in interior drainage ditch. (MN)*

Figure 2.56 *UNACCEPTABLE vegetation and sediment in interior drainage channel. (IA)*

Figure 2.57 *ACCEPTABLE interior ponding area and drainage ditch. (MN)*

b. Concrete Culverts/ Pipes

Figure 2.58 *Concrete drainage tunnel. (AK)*

All culverts must be clear of debris and must be structurally sound. Remember that inspections of drainage structures require compliance with confined space entry regulations. Any spalling in concrete culverts should be patched with an appropriate concrete material as described above. Repairs should be made to the bottom of the culvert if they show more than 1 inch of loss due to wear and abrasion. If significant settlement is detected in a culvert or pipe, it should be excavated, the foundation raised, the pipe replaced, the fill material added in four inch layers and compacted around the pipe to a density equal to or greater to that of the surrounding undisturbed material, and the area reseeded. Do not use a roller or heavy machinery to compact fill material when repairing the settlement over a culvert.

Figure 2.59 *The culvert on the left is Minimally Acceptable with sediment accumulation within the culvert. The culvert on the right is totally unacceptable with 2/3 of its flow capacity reduced by sediment and debris. This project was rated as UNACCEPTABLE because of the reduced flow capacity of the culverts. (MN)*

Figure 2.60 *MINIMALLY ACCEPTABLE, vegetation blocking the concrete culvert must be removed. (KS)*

c. Corrugated Metal Pipes

One significant maintenance item in many levee systems involves the repair and replacement of corrugated metal pipes (CMPs). Many levees all over the country were constructed with corrugated metal pipes to transport interior drainage, because CMP was one of the cheapest and most reliable materials available at the time. When the levees were constructed, the engineers designed them for an established design life (usually no more than 50 years), and since CMP was predicted to last for design life of the project, it was the material of choice for many drainage culverts. However, with many of the levees around the country at or beyond the design life of the CMP, it becomes critical that the pipes are inspected frequently and thoroughly, and replaced as needed. Remember that even if a CMP looks OK on the inside, the outside of the pipe may be very corroded and weak. Interior and exterior rust, reduction in metal thickness, joint separation, holes, and settlement, have all lead to the failure of the culverts. When a CMP fails during a flood, not only does the culvert cease to function as necessary, but material from the levee collapses to fill in the void, leaving a low spot in the crown of the levee. This low spot can quickly lead to a breach in the levee and the flooding of the protected area.

In some cases, a decaying CMP may temporarily be maintained by lining the pipe with an appropriate plastic liner or by patching it in various ways, but these are only temporary solutions and the pipe will eventually need to be replaced as part of the ongoing maintenance of the project. Because of this, you need to budget for the replacement of the pipes as their design life comes to an end. If it is noted during an inspection that a CMP culvert is Minimally Acceptable and the levee becomes damaged during a flood as a direct result of the failure of the CMP, then the Corps will deny post flood rehabilitation assistance for the repair of this damage. The maintenance and replacement of these pipes is considered to be part of the ongoing maintenance of the project and is therefore the responsibility of the public sponsor.

Figure 2.61 *UNACCEPTABLE, Failing corrugated metal pipe. DO NOT WALK INTO A FAILING CULVERT LIKE THIS. This section has actually separated, allowing the surrounding soil to enter the pipe and the overburden to collapse. This sponsor was denied rehabilitation assistance due to this maintenance deficiency.*

Figure 2.62 *Pieces of the same pipe, once removed from the levee. Note that while much of the pipe may have appeared to be in good condition from the inside, the outside was extremely corroded. The public sponsor attempted to patch the pipe the first year, but when it failed again, the entire CMP was replaced.*

d. Gated Structures

All flap gates, slide gates, and other gate systems need to be inspected and lubricated at least once a year just before the flood season. If gates aren't seated properly, water will flow back through the drainage structure during high water. During the inspection, all gates should be manually operated, and any debris or obstructions removed. All gate seats should be checked and the frames readjusted if the gate is not seating properly. Cracked or damaged gates need to be replaced. The inlet and outlet channels need to be kept free of debris, trees, brush and other vegetation, and sediment. All concrete cracks in the inlet/ outlet structure need to be repaired. Metal grates, hand wheels, and other metalwork should be secure and sound, free from rust, and regularly maintained by cleaning, painting, and greasing. If any pipe or culvert has separated from the inlet/ outlet structure headwall, this needs to be repaired as soon as possible. When high water is predicted, all flap and slide gates should again be inspected and any debris or obstructions should be removed immediately.

Figure 2.63 *ACCEPTABLE culvert gate. (LA)*

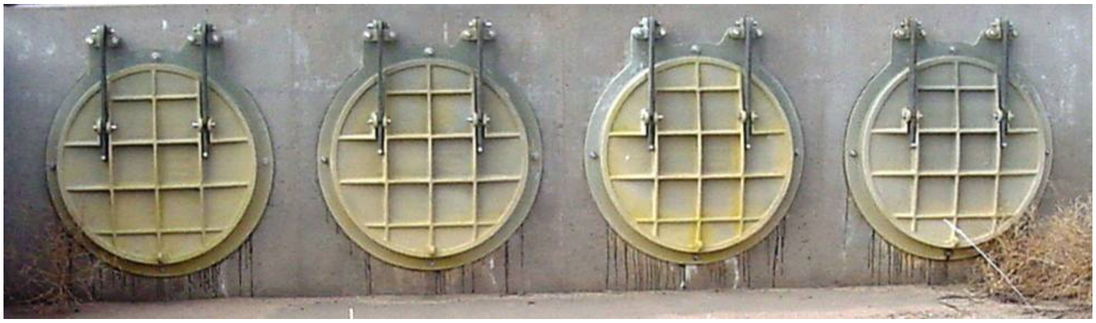

Figure 2.64 *ACCEPTABLE flap gates in earthen levee. (KS)*

Figure 2.65 *UNACCEPTABLE vegetation around flap gates in earthen levee. (OK)*

Figure 2.66 *UNACCEPTABLE flap gate in earthen levee. (Broken hinge and vegetation growth.) (MO)*

2.21 Pump Stations

Pump Stations should be inspected at least annually by the sponsor, preferably just before the flood season, following the manufacturers' publications and recommendations on maintenance. Preventative maintenance includes adjusting, lubricating, repairing, and replacing warn out or defective parts. A guide for the inspection frequencies and tasks for the various items of equipment is usually found in the manufacturer's recommendations, but may need to be adjusted depending on the frequency of operation of the pumping station. Any change to the manufacturer's recommendations should be coordinated with the manufacturer to avoid the possibility of voiding warranties.

Figure 2.67 *Hole in roof of pumping station. (IL)*

Some pump stations are located in remote areas and operated automatically. These stations may be easily overlooked, but need to be inspected, tested, and maintained just like any other pump station.

Megger tests need to be conducted at least every other year to ensure proper insulation of electrical components. While the cost of running the pumps typically prohibits the Corps from conducting a Megger test during continuing eligibility inspections, you need to conduct this test on your own when the pump is in operation. A logbook needs to be maintained at each pump station, which should include the date and type of testing conducted, the maintenance performed, and the number of hours each pump or piece of machinery was operated.

Figure 2.68 *Pump station beside earthen levee. (OK)*

Pump stations are exposed to potential fires, and should have adequate fire protection measures. This would include safety equipment for diesel generators and may include automatic sprinklers.

2.22 Flood Control Rivers and Channels

Figure 2.69 *UNACCEPTABLE vegetation in channel and sediment shoaling. (OK)*

Flood control channels should be inspected on a regular and continual basis to ensure that erosion is not causing bank instability that could result in a bank failure/ sloughing. When areas of bank instability or erosion are located, measures should be taken to correct the problem. If left unattended, the continued bank erosion will form sediment shoals within the river channel causing a reduction in channel capacity. As the shoals grow in size they begin to support vegetation and divert the channel flow into the river bank, causing additional bank erosion and instability. Trees that have fallen into the river channel or that may soon fall need to be removed to prevent log jams during high water, which can cause significant damage as described in section 2.5 above.

Sedimentation, silt, vegetation, downed trees, and other debris in the channel must be removed to maintain channel capacity. These materials should be disposed of in a manner that does not adversely affect the project or the floodway/floodplain. This improves water quality as well as helping prevent further flooding and maintenance problems. Before removing any sediment, trees, vegetation, or placing rock bank protections, you should contact the Corps' Regulatory Office and your local Department of Natural Resources to determine if any environmental permits are required.

Figure 2.70 *UNACCEPTABLE channel shoaling below a control structure. The original channel bottom extended all the way to the riprapped banks. There is an estimated 2-3 feet of sediment in the channel, mostly from upstream field erosion and highway construction. (MN)*

Figure 2.71 *MINIMALLY ACCEPTABLE shoaling within a concrete lined channel. (MN)*

2.23 Concrete Lined Channels

Concrete lined channels should be kept clear of debris, sediment, and vegetation. The concrete, flap gates, and other structures must be inspected annually and maintained as described in previous sections of this chapter. Sample maintenance and inspection activities may include (but are not limited to) clearing the sediment, vegetation, and debris; replacing joint seals as needed, and repairing damage to the concrete.

Figure 2.72 *ACCEPTABLE concrete lined flood control channel. (ID)*

Figure 2.73 *ACCEPTABLE intake structure upstream of the concrete channel. (ID)*

Figure 2.74 *ACCEPTABLE concrete lined channel. (AK)*

Figure 2.75 *UNACCEPTABLE vegetation and extensive sediment in channel. (TX)*

2.24 Debris Basins

Debris basins, sometimes called sediment retention basins, are reservoirs that are placed upstream of flood protection or navigation channels in order to collect sand, rocks, logs and other debris, and prevent it from obstructing the channel downstream. They help with flooding and navigation, and make the project easier to maintain, since it's easier to clean out the basin than to remove debris from the entire length of a channel.

As the basin fills up with sediment, the flowing water tends to take on the same width as the natural channel (rather than spreading over the surface of the basin), and the basin looses its ability to hold back as much debris. For this reason, debris basins are designed with the intent that they'll be periodically cleaned out. While some basins may have a 50 or 100-year capacity, others are sized for only one or two major storms.

Remove the sediment from the debris basin whenever it approaches one-half of its capacity by visual inspection, and whenever the deposits direct the flow against the channel or levee slope where they can cause erosion. Remove any large obstructions after every high-water event. The debris basin should kept be free from brush and trees, and sod should be maintained over the area to protect it from erosion.

The bottom of the basin slopes can erode during high water. Any eroded areas should be repaired as described in previous sections of this manual, and riprap or other erosion protection should be placed along the slopes to prevent further damage.

2.25 Floodways

A floodway is a designated piece of land that is purposefully left clear of development, for the purpose of passing floodwaters. When water rises beyond the capacity of the nearby rivers and channels, it then passes over this designated area. (In some areas of the country, the term floodway is used to designate the 100-year floodplain.) Floodways must be maintained so that when water passes over them, it doesn't rise beyond the expected levels. Obstructions such as earth deposits, debris, trash, undesirable vegetation, or unauthorized structures or encroachments reduce the floodway capacity and must be removed and disposed of properly. Vegetative growth that contributes to the preservation of natural resources and wildlife should be left alone unless the growth lessens the degree of protection or threatens the structural integrity of the project.